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Session 3A: Drinking Water

Kentucky Water Resources Research Institute, University of Kentucky

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Evaluating Potential Health Threats from Untreated Karst Springs as Community Drinking Water Sources, Monroe County, Kentucky*

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The geology of Southcentral Kentucky and Kentucky's Pennyroyal Plateau is characterized primarily by Mississippian-aged limestones that form prominent karst features such as caves and underground rivers. However, these prominent karst features offer markedly reduced filtration of contaminants that enter the groundwater system through the infiltration of surface water. Widespread agriculture in the region, including both livestock and row crop operations, can introduce dangerous contaminants to groundwater including fecal bacteria, pesticides, and fertilizers (White 1988; Currens 2002; Palmer 2007; Croskrey and Groves 2008). *E. coli,* a type of fecal coliform bacteria, is associated with gastro-enteric bloody diarrhea and sometimes fatal complications and has been the cause of large-scale acute GI infection outbreaks (Levine 1987; Nataro and Kaper 1988; Valcour et al. 2002; Tarr et al. 2005; Amraotkar et al. 2015). For this reason, the use of untreated karst groundwater as a drinking water source has been virtually eliminated in locations with highly-developed water supply and treatment infrastructure such as Southcentral Kentucky.

Despite the inherent risks in utilizing untreated karst groundwater as drinking water, two families in "simple living" Mennonite and Quaker communities in Southcentral Kentucky choose to utilize untreated karst groundwater as their primary drinking water source instead of implementing reliable disinfection methods or connecting to local municipal water supplies. These families choose to consume untreated karst groundwater based upon the ideology that "natural" water is safer since it is void of the chlorine and fluoride that are conventionally added to treated water and because it is cost prohibitive to connect to local municipal water supply infrastructure.

In 2015, a study (Amraotkar et al. 2015) was published that examined the relationship between Mennonite lifestyle and fecal bacteria contamination in drinking water in Allen County, Kentucky. Even so, the true extent of this local public health issue in simple-living communities of Southcentral Kentucky is unknown. The study also did not consider hydrogeologic variables, including karst. This project is the first to examine the relationship between Mennonite and Quaker communities and highly vulnerable *karst* groundwater sources in Southcentral Kentucky. It also represents the first phase of a new research program for Western Kentucky University's Crawford Hydrology Laboratory. The *long-term* goals of this program are to use these communities as demonstration sites to 1) evaluate the nature and extent of contaminated, untreated karst drinking water sources; 2) develop a participatory educational/technical approach to raise awareness of drinking water safety; and 3) evaluate a range of potential water resource protection strategies.

Through this project, three springs and one post-filtration home faucet are sampled monthly in a synoptic, non-conditional program with timing based on the US Geological Survey (USGS) National Water Quality Assessment (NAWQA) (USGS 2017). Sampling is synoptic in that it provides a synopsis of the conditions at the selected sites and non-conditional in that the samples

are collected on pre-selected days. Sampling began in March with a completion target of May 2019. The four sites consist of Springhouse Spring 001 (secondary water source for Family #1, no filtration), Springbox Spring 002 (primary water source for Family #1, filtered before use), Home Faucet 003 (primary water source for Family #1 supplied from Springbox Spring and filtered), and Cave Spring 004 (primary water source for Family #2). Regular sampling includes collection of water samples for the measurement of anions (to measure nitrate NO_3^-), cations (to measure ammonia NH_4^+), turbidity (by colorimeter), total coliform, and *E. coli* at all locations and the measurement of pH, specific conductivity, and temperature at each site except for Home Faucet 003. In addition, temperature, depth, pH, and conductivity are continuously recorded with a YSI data sonde every fifteen minutes at Springhouse Spring 001.

Preliminary results of the analytical component of the project indicate that while Cave Spring 004 is a highly contaminated drinking water source utilized by Family #2, the filtration system utilized by Family #1 is generally effective at disinfecting faucet water (Home Faucet 003) derived from Springbox Spring 001. Total coliform and *E. coli* measurements have indicated concentrations consistently above EPA primary drinking water standard maximum contaminant levels (MCLs) at all sites except at Home Faucet 003, which demonstrated <1 most probable units per 100 mL (MPN) of total coliform except in the months of May (5.2 MPN total coliform) and August (133.3 MPN total coliform). Family #1 was notified at each of these findings. All Home Faucet 003 samples collected to date show a concentration of <1 MPN of *E. coli*. At all sites, pH and total dissolved solids (measured in terms of conductivity) have been below EPA secondary drinking water standard MCLs and turbidity measurements have varied from <5 FAU to a maximum of 12 FAU. EPA primary drinking water standards dictate that drinking water should be characterized by a turbidity of no higher than 5 NTU (where one NTU is roughly equivalent to one FAU when measuring formazin). Ion data processing is ongoing.

Preliminary results of the community outreach portion of the project have resulted in benefits to both families. After discussing the contaminated nature of Cave Stream 004 with Family #2, the family discontinued the use of Cave Spring 004 as their primary drinking water source and is drinking bottled water until they complete the installation of a reverse osmosis filtration system. Preliminary results have also been shared with Family #1 whose confidence is restored in their home water purification system. Efforts are ongoing to raise awareness of drinking water safety in the neighboring Mennonite and Quaker communities and it is hoped that through the continuation of this project other community members may be reached or will reach out to the principal investigators with water quality inquiries.

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Benefits of Energy Savings Performance Contracting for Water and Wastewater Treatment Facilities

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Communities across the Commonwealth are taking advantage of the state statute **KRS 45A.352 Guaranteed energy savings contracts involving local public agencies.** This statute allows for the upgrading and updating of publicly owned buildings and facilities with new energy efficient materials and equipment. Municipal water and wastewater plants are benefitting economic benefits through reduced energy and maintenance costs and increased income.

The Kentucky Energy and Environment Cabinet, the Kentucky Department for Local Government and the University of KY's Center for Applied Energy Research (CAER) have developed the Local Government Energy Retrofit Program (LGERP) to assist local agencies to work with Energy Services Companies (ESCo) in negotiating, developing and contracting an Energy Savings Performance Contract (ESPC). Under an ESPC, savings achieved in energy or operational costs and capital avoidance costs not to exceed 50% of total project costs, are guaranteed to pay for the project including debt service. Failure to achieve agreed upon savings requires the ESCo to make up the financial difference between actual costs versus the guaranteed savings.

It is generally acknowledged that water and wastewater facilities consume up to 35% of a municipality's energy budget. It is also acknowledged ESPCs achieve 15%- 25% savings. Savings are achieved through replacing existing equipment that is at or beyond its useful life with new energy efficient products. This can include plant equipment, pump and lift stations as well as meters.

Under LGERP, CAER staff works with communities to develop a Request for Proposal, accumulate 2 years of recent energy bills, and participate in mandatory pre-bid meetings and walkthroughs. Assistance in evaluating proposal submissions, ESCo selection and contract negotiation is also provided. This is provided at no cost to the local agency.

Successful projects to date include: Williamsburg, Greensburg, Greenville (underway), and Louisa. CAER is currently working with three municipalities in anticipation of RFP issuance and potential ESPC. A review of current projects and status updates of the anticipated projects as well as detailed explanations of the process will be provided.

Self-Cleaning Nanocomposite Membranes with Phosphorene-Based Pore Fillers for Water Treatment

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Phosphorene is a two-dimensional material exfoliated from bulk phosphorus and it possesses a band gap. Specifically, relevant to the field of membrane science, the band gap of phosphorene provides it with potential photocatalytic properties, which could be explored in making reactive membranes that can self-clean. The goal of this study was to develop an innovative and robust membrane that is able to control and reverse fouling with minimal changes in membrane performance. To this end, for the first time, membranes have been embedded with phosphorene. Membrane modification was verified by the presence of phosphorus on membranes, along with changes in surface charge, average pore size, and hydrophobicity. After modification, phosphorene-modified membranes were used to filter methylene blue (MB) under intermittent ultraviolet light irradiation. Phosphorene-modified and unmodified membranes displayed similar rejection of MB; however, after reverse-flow filtration was performed to mimic pure water cleaning, the average recovered flux of phosphorene-modified membranes was four times higher than that of unmodified membranes. Furthermore, coverage of MB on phosphorene membranes after reverse-flow filtration was four times lower than that of unmodified membranes, which supports the hypothesis that phosphorene membranes operated under intermittent ultraviolet irradiation can become self-cleaning.